10/589616
IAP6 Rec'd PCT/PTO 16 AUG 2006

SPECIFICATION

COIL, AND ANTENNA AND TRANSFORMER USING THE COIL

Technical Field

[0001]

The present invention relates to a coil, and an antenna and a transformer using the coil.

Background Art

[0002]

As shown in Figure 9, for example, conventionally in a typical coil 510 used for an antenna and a transformer, a conductor 531 is wound from one end (flange portion 522a) to the other end (flange portion 522b) of a winding shaft portion 521 along the surface of the winding shaft portion 521 to form a first layer, and then the conductor 531 is in a reversed direction wound from the other end (flange portion 522b) to the one end (flange portion 522a) to form a second layer. Thereafter, the conductor 531 is similarly wound in alternately reversed directions to form a third layer and a fourth layer, so that a winding portion (coil portion) 530 is formed. Such a winding operation is called solenoid winding.

[0003]

When the coil manufactured by solenoid winding is used as an antenna coil, a capacitor is connected in parallel with the coil, and the leading end and the terminal end of the conductor forming the coil are connected to the main part of a receiver, so that data can be received at a predetermined resonance frequency.

[0004]

Generally in such a coil, stray capacitance components (parasitic capacitance components) occur between turns of conductor (coil) or terminal electrodes, and the stray capacitance components and the inductance components of the coil cause a resonance phenomenon. The resonance frequency of such a resonance phenomenon is called "self

resonant frequency" and is the maximum frequency used for a coil (inductor) on a circuit. In general a frequency used for a coil is equal to or lower than one half to one fifth of the self resonant frequency.

[0005]

As described above, in the antenna coil manufactured by solenoid winding, the conductor is wound from one end to the other end of the core, and then the conductor is in a reversed direction wound from the other end to the one end. For example, in Figure 9, conductors adjacent to each other in the vertical direction on the one end are quite different in the number of turns. In other words, a length L2 of the layers is large and causes large stray capacitance components. The same phenomenon occurs on the second layer and the third layer on the other end.

[0006]

Such large stray capacitance components considerably reduce the self resonant frequency. When the self resonant frequency considerably decreases and the used frequency is brought close to the lower part of the self resonance peak, the inductance value at the used frequency is widely varied among parts due to variations in performance among the parts. Further, when the used frequency is brought close to the lower part, the inductance value is widely varied also by temperature variations.

[0007]

The inductance value of the coil, along with the capacitance of the capacitor, is a factor for determining the frequency to be used. A corresponding inductance value is set for each frequency to be used. When the inductance value varies, the resonance frequency for reception is displaced, so that reception at the used frequency becomes difficult and a coverage is reduced.

[0008]

In response to this problem, the applicant has developed an antenna coil (Patent document 1). The coil has a winding portion formed with a core having flange portions on both ends. In the winding portion, layers of conductor are wound one by one from one of the flange portions such that outer layers of conductor incline to the flange portion.

The winding operation is performed while being shifted to the other flange portion of the core.

[0009]

In the antenna coil, the winding portion is formed by a winding method called oblique winding (bank winding) which can produce an excellent effect of reducing stray capacitance components occurring between layers of wound conductor.

[0010]

Another method for reducing stray capacitance components occurring between layers of wound conductor may be to divide a winding portion into a plurality of sections.

[0011]

Patent document 1: Japanese Unexamined Patent Publication No. 2003-332822

Disclosure of the Invention

Problems to be solved by the Invention

[0012]

However, when a winding portion is formed by oblique winding (bank winding), layers of conductor may collapse in the process of winding the conductor, which may cause low product quality such as an unstable coil characteristic.

[0013]

Moreover, when performing winding after dividing a winding portion into a plurality of sections, flange portions are necessary between sections in order to prevent layers of conductor from collapsing on the ends of the sections. Thus it is difficult to miniaturize the product. The method for dividing a winding portion into a plurality of sections is particularly unsuitable for an antenna coil because the coil has to be miniaturized. Such an antenna coil to be miniaturized is used for a radio communication technique such as RFID (Radio Frequency-Identification), for example, remote keyless entry for automobiles and an air pressure sensor of a tire.

[0014]

Also in a transformer coil, winding is generally performed after a winding portion is divided into a plurality of sections in order to reduce a potential difference between the

leading end and the terminal end of a secondary winding. Also in this case, flange portions are necessary between the sections, so that it is difficult to reduce the size and cost of the product.

[0015]

The present invention is proposed in view of these circumstances. An object of the present invention is to provide a coil in which stray capacitance components between layers of wound conductor are reduced, so that fluctuations in the inductance value of the coil are reduced and the size and cost of a product can be reduced. The inductance value fluctuates due to differences in characteristics among parts or temperature variations.

Means for solving the Problems

[0016]

In order to attain the object, a coil of the present invention comprises a core which has two flange portions and is made of a magnetic material, and a winding portion made up of a plurality of layers of conductor wound around the core between the two flange portions of the core,

characterized in that the winding portion is divided into a plurality of sections between the two flange portions, one layer of conductor is wound from one end to the other end in each section, and then layers of conductor are wound in alternately reversed directions to form a multilayer winding portion by solenoid winding.

[0017]

The winding portion is preferably formed by winding the conductor such that a boundary surface between adjacent sections inclines to the flange portion at the winding start and the boundary surface of an upper layer is closer to the flange portion than the boundary surface of a lower layer.

[0018]

The winding portion is preferably formed by winding the conductor such that in each end section, at least a portion near an upper layer of an end face facing the flange portion is apart from the flange portion so as to be farther from the flange portion than a lower layer of the end face.

[0019]

The coil of the present invention can be used as an antenna coil or a transformer coil.

Effect of the Invention

[0020]

As described above, in the coil of the present invention, the winding portion is divided into a plurality of sections and the conductor is wound around the core by solenoid winding in each section, thereby remarkably reducing a stray capacitance occurring between layers of wound conductor as compared with the prior art in which solenoid winding is performed on the overall length of the core.

[0021]

Since the flange portions are not necessary between the sections, the size and cost of the product can be reduced.

[0022]

The conductor is wound such that the boundary surface between adjacent sections inclines to the flange portion at the winding starting and the boundary surface of an upper layer is closer to the flange portion than that of a lower layer. Thus layers of conductor do not collapse on the boundary surface of each section and a high quality coil can be obtained.

[0023]

It is wound the conductor such that in each end section, at least a portion near an upper layer of the end face facing the flange portion is apart from the flange portion so as to be farther from the flange portion than a lower layer of the end face. Thus a gap appears between the flange portion and the upper layer of the winding portion. Even the conductor is soldered in the vicinity of the flange portion, melted solder does not adhere between the flange portion and the winding portion and thus does not cause poor insulation.

Best Mode for Carrying Out the Invention

[0024]

The following will specifically describe a coil according to embodiments of the present invention with reference to the accompanying drawings.

<First Embodiment>

Figure 1 is a partial sectional view showing an antenna coil according to a first embodiment of the present invention. Figure 2 is a perspective view showing the core of the antenna coil.

[0025]

A core 20 used for an antenna coil 10 according to the first embodiment of the present invention includes, as shown in Figure 2, flange portions 22a and 22b on both ends of a prismatic winding shaft portion 21. The core 20 is made of a ferrite material, which has excellent magnetic properties, with an overall length of about 1 cm.

[0026]

On the core 20, a winding portion 30 is divided into a plurality of sections, and a thin conductor is wound about 700 to 800 turns in each section by solenoid winding, so that the antenna coil 10 is formed.

[0027]

In solenoid winding, the conductor is wound from one end to the other end of the winding shaft portion 21 along the surface of the winding shaft portion 21 to form a first layer, and then the conductor is in a reversed direction wound from the other end to the one end to form a second layer. Thereafter, the conductor is similarly wound in alternately reversed directions to form a third layer and a fourth layer.

[0028]

To be specific, as shown in Figure 1, the winding portion 30 is divided into four sections of a first section 30a, a second section 30b, a third section 30c, and a fourth section 30d in this order from the left. In the first section 30a, the conductor is wound from one end of the winding shaft portion 21 (flange portion 22a) to the other end (second section 30b) along the surface of the winding shaft portion 21 to form a first layer, and then the conductor is in a reversed direction wound from the other end (second section 30b) to the one end (flange portion 22a) to form a second layer. Thereafter, the

conductor is wound in alternately reversed directions to form a third layer and a fourth layer, so that the winding of the first section 30a is completed.

[0029]

Subsequently in the second section 30b, the conductor is wound from one end of the winding shaft portion 21 (first section 30a) to the other end (third section 30c) along the surface of the winding shaft portion 21 to form a first layer, and then the conductor is in a reversed direction wound from the other end (third section 30c) to the one end (first section 30a) to form a second layer. Thereafter, the conductor is similarly wound in alternately reversed directions to form a third layer and a fourth layer, so that the winding of the second section 30b is completed.

Then, a conductor 31 is wound in the third section 30c and the fourth section 30d through the same steps, so that the winding operation is completed.

[0030]

<Second Embodiment>

Figure 3 is a partial sectional view showing an antenna coil according to a second embodiment of the present invention.

A antenna coil 110 according to the second embodiment of the present invention is similar to the antenna coil 10 according to the first embodiment in that a winding portion 130 is divided into four sections of a first section 130a, a second section 130b, a third section 130c, and a fourth section 130d in this order from the left and a conductor 131 is wound in each section by solenoid winding. The coil 110 is different from the coil 10 according to the first embodiment in that the conductor 131 is wound such that the boundary surface between adjacent sections inclines to a flange portion 122a, which is the winding start, and the boundary surface of an upper layer is closer to the flange portion 122a than that of a lower layer.

[0031]

To be specific, as shown in Figure 3, in the first section 130a, the conductor is wound from one end of a winding shaft portion 131 (flange portion 122a) to the other end (second section 130b) along the surface of the winding shaft portion 121 to form a first

layer, and then the conductor is in a reversed direction wound from the other end (second section 130b) to the one end (flange portion 122a) to form a second layer. Thereafter, the conductor is wound in alternately reversed directions to form a third layer and a fourth layer, so that the winding of the left end section is completed.

[0032]

In this case, the conductor 131 is wound to form the second layer such that the end face of the winding portion 130 is in contact with the flange portion 122a and the number of turns of the second layer is reduced from that of the first layer by about 50 turns. Then, the conductor 131 is wound to form the third layer such that the number of turns of the third layer is reduced from that of the second layer by about 50 turns. Further, the conductor 131 is wound to form the fourth layer such that the number of turns of the fourth layer is reduced from that of the third layer by about 50 turns. In this way, the conductor 131 is wound in alternately reversed directions while the number of turns is reduced.

[0033]

Subsequently in the second section 130b and the third section 130c, the conductor 131 is wound by solenoid winding such that the winding portion 130 is shaped like a parallelogram in cross section.

Then, in the fourth section 130d, the conductor 131 is wound by solenoid winding in alternately reversed directions and the number of turns is increased such that the end face of the winding portion 130 is in contact with the flange portion 122b, so that the winding operation is completed.

[0034]

The conductor 131 is wound through the foregoing steps, so that the boundary surface between adjacent sections inclines to the flange portion 22a, which is the winding start, and the boundary surface of an upper layer is closer to the flange portion than that of a lower layer. It is thus possible to positively prevent layers of conductor from collapsing on the boundary surface of each section.

[0035]

<Third Embodiment>

Figure 4 is a partial sectional view showing an antenna coil according to a third embodiment of the present invention. Figure 5 is a perspective view showing the antenna coil according to the third embodiment of the present invention.

[0036]

An antenna coil 210 according to the third embodiment of the present invention is similar to the antenna coil 10 according to the first embodiment in that a winding portion 230 is divided into four sections of a first section 230a, a second section 230b, a third section 230c, and a fourth section 230d in this order from the left and a conductor 231 is wound in each section by solenoid winding. The coil 210 is different from the coil 10 according to the first embodiment as follows: the conductor 231 is wound such that in each end section, portions near upper layers of end faces facing flange portions 222a and 222b are apart from the flange portions 222a and 222b so as to be farther from the flange portions than lower layers of the end faces.

[0037]

As shown in Figures 4 and 5, the flange portions 222a and 222b of a core 220 include binding portions 241a and 241b protruding to the outside. The binding portions 241a and 241b are bound with the ends of the conductor 231, so that the ends of the conductor 231 are fixed.

[0038]

The binding portions 241a and 241b are parts of terminal members 240a and 240b which are detachably attached to the main portions of the flange portions 222a and 222b. The terminal members 240a and 240b are almost shaped like letter C in cross section and made of a synthetic resin or the like having elasticity and flexibility. The terminal members 240a and 240b are engaged to the main portions of the flange portions 222a and 222b, so that the entire flange portions 222a and 222b are formed.

[0039]

In the coil of the third embodiment, as shown in Figure 4, the winding portion 230 is divided into four sections of the first section 230a, the second section 230b, the third

section 230c, and the fourth section 230d in this order from the left. In the first section 230a, the conductor is wound from one end of the winding shaft portion 221 (flange portion 222a) to the other end (second section 230b) along the surface of the winding shaft portion 221 to form a first layer, and then the conductor is in a reversed direction wound from the other end (second section 230b) to the one end (flange portion 222a) to form a second layer. Thereafter, the conductor is wound in alternately reversed directions to form a third layer and a fourth layer, so that the winding of the first section 230a is completed.

[0040]

In this case, the conductor 231 is wound to form (n + 1)th layer such that a portion near the upper layer of the end face facing the flange portion 222a is apart from the flange portion 222a. For example, in the upper layer of n-th layer, the number of turns is reduced from that of n-th layer by about 50 turns. Then, the conductor 231 is wound to form (n + 2)th layer. The number of turns of the (n + 2)th layer is reduced from that of (n + 1)th layer by about 50 turns. Further, the conductor 231 is wound to form (n + 3)th layer. The number of turns of (n + 3)th layer is reduced from that of (n + 2)th layer by about 50 turns. In this way, the conductor 231 is wound in alternately reversed directions while the number of turns is reduced in upper layers. In this case, n represents a positive natural number.

[0041]

The reduction in the number of turns may be started from any one of the layers. Instead of reducing the number of turns in each layer, the number of turns may be reduced, for example, every two layers or three layers.

[0042]

Subsequently in the second section 230b and the third section 230c, the conductor 231 is wound through the same steps as the first embodiment.

Finally also in the fourth section 230d, the conductor 231 is wound through the same steps as the first section 230a while the number of turns is reduced in upper layers, so that the winding operation is completed.

[0043]

The conductor 231 is wound through these steps, so that the end faces of the winding portion 230 facing the flange portions 222a and 222b are apart from the flange portions 222a and 222b such that an upper layer is farther from the flange portions 222a and 222b than a lower layer. Even when gaps appear between the upper portions of the flange portions 222a and 222b and the winding portions 230a and 230d and the conductor 231 is soldered in the vicinity of the flange portions 222a and 222b, melted solder does not adhere between the flange portions 222a and 222b and the winding portions 230a and 230d and thus does not cause poor insulation.

[0044]

<Fourth Embodiment>

Figure 6 is a plan view showing a transformer coil according to a fourth embodiment of the present invention. Figure 7 is a partial sectional view showing the transformer coil according to the fourth embodiment of the present invention.

[0045]

In a transformer coil 310 according to a fourth embodiment of the present invention, a winding portion 330 is divided into four sections on a secondary winding, and a conductor 331 is wound by solenoid winding in each section. The conductor 331 on the secondary winding is wound through almost the same steps as the antenna coil 10 according to the first embodiment.

[0046]

To be specific, as shown in Figures 6 and 7, the transformer coil 310 according to the fourth embodiment of the present invention includes a coil bobbin 370, an I-shaped core 360 inserted into the coil bobbin 370, a C-shaped core 350 placed on both ends of the I-shaped core 360, and a terminal support 380 having terminals 381a to 380f for connecting a primary winding and the secondary winding.

[0047]

The I-shaped core 360 and the C-shaped core 350 are made of a ferrite material having excellent magnetic properties.

[0048]

The coil bobbin 370 has flange portions 371a, 371b, and 371c for winding a primary winding 340 and a secondary winding 330. Of the flange portions 371a to 371c, the flange portions 371a and 371c are disposed respectively on both ends of the coil bobbin 370, and the flange portion 371b is disposed on the boundary of the primary winding 340 and the secondary winding 330.

[0049]

On the primary winding 340, a conductor 341 is wound by solenoid winding along an overall length between the flange portion 371a and the flange portion 371b.

[0050]

The secondary winding 330 is divided into four sections of a first section 330a, a second section 330b, a third section 330c, and a fourth section 330d in this order from the left. In the first section 330a, the conductor is wound from one end of the coil bobbin 370 (flange portion 371b) to the other end (second section 330b) along the surface of the coil bobbin 370 to form a first layer, and then the conductor is in a reversed direction wound from the other end (second section 330b) to the one end (flange portion 371b) to form a second layer. Thereafter, the conductor is wound in alternately reversed directions to form a third layer and a fourth layer, so that the winding of the first section 330a is completed.

[0051]

Subsequently in the second section 330b, the conductor is wound from the one end of the coil bobbin 370 (first section 330a) to the other end (third section 330c) along the surface of the coil bobbin 370 to form a first layer, and then the conductor is in a reversed direction wound from the other end (third section 330c) to the one end (first section 330a) to form a second layer. Thereafter, the conductor is similarly wound in alternately reversed directions to form a third layer and a fourth layer, so that the winding of the second section 330b is completed.

[0052]

Then the conductor 331 is wound in the third section 330c and the fourth section 330d through the same steps, so that the winding operation is completed.

[0053]

<Stray capacitance occurring between layers of wound conductor>

As described above, the winding portion is divided into a plurality of sections and the conductor is wound by solenoid winding in each section according to the embodiments of the present invention, so that a stray capacitance occurring between layers of wound conductor can be considerably reduced as compared with the prior art in which a conductor is wound by solenoid winding along the overall length of a winding portion.

[0054]

In other words, the length L1 of layers is about one fourth the length L2 of layers in the example of Figure 9 illustrating the prior art. It is evident that the embodiments of the present invention can dramatically reduce the length of layers. Thus it is possible to considerably reduce stray capacitance components.

[0055]

The following will describe a reduction of stray capacitance components in the antenna coil according to the present embodiment.

In the antenna coil according to the present embodiment, stray capacitance components can be considerably reduced and thus it is possible to increase the value of self resonant frequency f_P (= $1/(2\pi(LC_P)^{1/2})$) which is resulted from stray capacitance component C_P and inductance component L of the coil (inductor).

[0056]

The self resonant frequency considerably increases thus and the frequency to be used (resonance frequency to be used) can be placed on a part which is apart from the lower part of the self resonance peak to the low frequency side and has a stable characteristic. Therefore even in the presence of variations in performance between the parts or large fluctuations in ambient temperature, the inductance value does not greatly vary at the used frequency.

[0057]

As described above, the inductance value, along with the capacitance of the capacitor, is a factor for determining the frequency to be used. A corresponding inductance value is set for each frequency to be used. According to the present embodiment, the inductance value does not greatly vary at the used frequency and thus the resonance frequency for reception is stabilized, so that reception at the used frequency does not become difficult or a coverage is not reduced.

[0058]

Figure 8 is a circuit diagram showing an example in which the antenna coil according to the present embodiment is used for a typical switching circuit. To be specific, a capacitor 420 with a predetermined capacitance is connected in parallel with an antenna coil 410, and both ends of the conductor of the antenna coil 410 are connected to receiving means 430. The receiving means 430 can open or close a switch 440.

[0059]

The antenna coil 410 resonates in response to a radio signal of a used frequency of $f(= 1/(2\pi(LC)^{1/2}))$, which is determined by the inductance component L and the capacitance component C of the capacitor 420. It is accordingly recognized that the receiving means 430 has received a predetermined signal. The receiving means 430 closes the switch 440 in response to the recognition, so that the circuit including the switch 440 is turned on. The antenna coil 410 according to the present embodiment is used for such a switching circuit, so that receiving sensitivity does not decrease even in the presence of variations in properties between parts or large fluctuations in ambient temperature. Thus no malfunction occurs when the circuit including the switch 440 is turned on/off.

[0060]

Further, in the transformer coil according to the present embodiment, the secondary winding is divided into a plurality of sections (for example, four sections) and thus a potential difference between the leading end and the terminal end of the secondary winding can be reduced. In this case, flange portions are not necessary between the sections and thus it is possible to reduce the size and cost of the product.

[0061]

<Another Embodiment>

The coil of the present invention is not limited to the foregoing embodiments and various modification can be made. For example, although the two flange portions are formed on both ends of the core in the antenna coil, the flange portions may be formed at some points of the core.

[0062]

Moreover, the number of divisions of the winding portion is not limited to those of the embodiments and can be changed as appropriate.

[0063]

The core, the I-shaped core, and the C-shaped core are made of ferrite. The material of the core is not limited to ferrite and may be selected from other typical core materials (ferromagnetic materials). For example, it is possible to use materials such as Permalloy, Sendust and iron carbonyl and a dust core formed by compression molding fine powder of these materials.

Brief Description of the Drawings

[0064]

Figure 1 is a partial sectional view showing an antenna coil according to a first embodiment of the present invention;

Figure 2 is a perspective view showing the core of the antenna coil according to the first embodiment of the present invention;

Figure 3 is a partial sectional view showing an antenna coil according to a second embodiment of the present invention;

Figure 4 is a partial sectional view showing an antenna coil according to a third embodiment of the present invention;

Figure 5 is a perspective view showing the antenna coil according to the third embodiment of the present invention;

Figure 6 is a plan view showing a transformer coil according to a fourth embodiment of the present invention;

Figure 7 is a partial sectional view showing the transformer coil according to the fourth embodiment of the present invention;

Figure 8 is a circuit diagram showing an example in which the antenna coil according to the present embodiment is used for a typical switching circuit; and

Figure 9 is a partial sectional view showing a typical coil used for a conventional antenna or transformer.

Description of Symbols

[0065]

10, 110, 210, 310, 410 antenna coil

20, 120, 220, 320 core

21, 121, 221 winding shaft portion

22a, 22b, 122a, 122b, 222a, 222b flange portion

30, 130, 230, 330 winding portion

30a, 130a, 230a, 330a first section

30b, 130b, 230b, 330b second section

30c, 130c, 230c, 330c third section

30d, 130d, 230d, 330d fourth section

31, 131, 231, 331 conductor

241a, 241b binding portion

240a, 240b terminal member

310 transformer coil

330 secondary winding

340 primary winding

341 conductor of the primary winding

350 C-shaped core

360 I-shaped core

370 coil bobbin

371a to 371c flange portion

380 terminal support

381a to 381f terminal

420 capacitor

430 receiving means

440 switch

510 conventional coil

521 winding shaft portion

522a, 522b flange portion

530 winding portion

531 conductor